

Circumstances and causes of out-of-hospital cardiac arrest in sudden death survivors

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Abstract

Objective—To study the circumstances and medical profile of out-of-hospital sudden cardiac arrest (SCA) patients in whom resuscitation was attempted by the ambulance service, and to identify causes of SCA in survivors and factors that influence resuscitation success rate.

Methods—During a five year period (1991–95) all cases of out-of-hospital SCA between the ages of 20 and 75 years and living in the Maastricht area in the Netherlands were studied. Information was gathered about the circumstances of SCA, as well as medical history for all patients in whom resuscitation was attempted by the ambulance personnel. Causes of SCA in survivors were studied and logistic regression analysis was performed to identify factors associated with survival.

Results—Of 288 SCA patients in whom cardiopulmonary resuscitation (CPR) and advanced life support were applied, 47 (16%) were discharged alive from the hospital. Their mean (SD) age was 58 (11) years, 37 (79%) were men, and 24 (51%) had a history of cardiac disease. Acute myocardial infarction was diagnosed in 24 (51%) of the survivors; seven with and 17 without a history of cardiac disease. Ventricular fibrillation (VF) or ventricular tachycardia (VT) as the first documented rhythm was significantly positively associated with survival (odds ratio (OR) 5.7, 95% confidence interval (CI) 2.1 to 15.9). A time interval of less than four minutes between the moment of collapse and the start of resuscitation, and an ambulance delay time of less than eight minutes were significantly positively associated with survival (OR 3.3, 95% CI 1.3 to 8.6, and OR, 3.6, 95% CI 1.3 to 10.5, respectively). A history of cardiac disease was negatively associated with survival (OR 0.46, 95% CI 0.21 to 0.98).

Conclusions—Acute myocardial infarction was the underlying mechanism of SCA in most of the survivors, especially in those without a history of cardiac disease. CPR within four minutes, an ambulance delay time less than eight minutes, and VT or VF diagnosed by the paramedics were positively associated with success.

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Unexpected cardiac arrest continues to be an important cause of death in the industrialised world. Unfortunately only a small proportion of out-of-hospital sudden cardiac arrest (SCA) patients survive to hospital discharge. Study of survivors of SCA can give more insight into the circumstances and underlying mechanisms of SCA. Results of studies^{1–4} on the cause of SCA in survivors are contradictory. In the classic study from Seattle, only 20% of survivors had a new transmural infarction.¹ In contrast, a more recent study by Dickey *et al* reported that the cause of ventricular fibrillation was acute myocardial infarction (MI) in 69% of patients who were successfully resuscitated.³ We have studied the causes of SCA in survivors and investigated factors determining survival in patients in whom resuscitation was attempted by the ambulance personnel.

Methods

PATIENTS

During a five year period (1 January 1991 to 31 December 1995) 638 cases of unexpected out-of-hospital SCA occurred in people between the ages of 20 and 75 years who lived in the Maastricht region of the Netherlands. This area of 203 square kilometres has approximately 182 000 inhabitants of whom about 133 000 (73%) are between the ages of 20 and 75 years. The area has one ambulance service with seven ambulances. All seven ambulances are equipped with defibrillators, material for intubation and oxygen administration, and drugs such as adrenaline, atropine, lidocaine, and procainamide. The ambulance service can be contacted 24 hours a day by telephoning 112. Each ambulance has one nurse and one driver. In case of SCA, two ambulances are immediately directed to the scene.⁵

INCLUSION CRITERIA

Included in this study were all witnessed and unwitnessed victims of SCA living in the study region in whom resuscitation was attempted by the ambulance personnel. Excluded were patients with a circulatory arrest following a traumatic event or intoxication, or SCA occurring in the terminal phase of a chronic disease.⁵

DATA COLLECTION

All cases of out-of-hospital SCA in the Maastricht region were recorded by contacting the ambulance service each day. The data were analysed from SCA patients in whom resuscitation was attempted by the ambulance personnel.

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Table 1 Baseline characteristics and circumstances of sudden cardiac arrest in patients who were resuscitated by ambulance personnel

	Survivors (n = 47)	Non-survivors (n = 241)	p value
Men	37 (79%)	187 (78%)	
Women	10 (21%)	54 (22%)	NS
Mean age (years)	58.1 (11.3)	60.7 (9.8)	NS
Cardiac history	24 (51%)	139 (58%)	NS
Event at home	24 (51%)	162 (67%)	0.05
Witnessed SCA	45 (96%)	212 (88%)	NS
Resuscitation by bystander	28 (60%)	102 (42%)	< 0.05
First documented rhythm VT or VF	40 (85%)	123 (51%)	< 0.001
Resuscitated within 4 minutes of the moment of collapse	34 (72%)	105 (44%)	< 0.001
Ambulance delay time less than 8 minutes	41 (87%)	167 (69%)	< 0.05

VT, ventricular tachycardia; VF, ventricular fibrillation.

Information was collected about age, sex, circumstances (place, time, complaints present before the event), whether and by whom the SCA was witnessed, and whether resuscitation had already been initiated by a witness or bystander. This information was obtained from the ambulance personnel, the general practitioner, and by interviewing witnesses or family members and the patient when possible. Information about the cardiac rhythm at the moment of arrival of the ambulance, the estimated time between the moment of collapse and the start of the resuscitation, and the ambulance delay time (time between the moment of the emergency call and the moment of arrival) were obtained from a questionnaire filled out by the ambulance personnel immediately after the event.

All patients discharged alive from the hospital had been admitted to the coronary care unit of the department of cardiology at the academic hospital in Maastricht. In all survivors serial electrocardiograms (ECG) and serum cardiac enzymes (creatinine kinase (CK) and CK-MB, alanine aminotransferase (ALT), aspartate aminotransferase (AST), and lactic dehydrogenase (LDH)) were determined. In all but two patients echocardiography was performed during hospital stay. In 34 patients a coronary angiogram, and in selected patients electrophysiological studies were performed. In all patients the cause of SCA was determined by consensus between the staff cardiologists of the department.

Information about the patient's medical history and morbidity was collected from the patient's general practitioner file and from hospital records. Information about admission to a nursing home and mortality after discharge was obtained by contacting the patient's general practitioner.

Table 2 Results of multiple logistic regression analysis, with survival as the dependent variable

Variables	Odds ratios (95% CI)
Sex: male v female	1.39 (0.54 to 3.62)
Age (years)	0.97 (0.93 to 1.00)
Previous cardiac history (yes/no)	0.46 (0.21 to 0.98)
Location of the event: at home/not at home	0.84 (0.38 to 1.87)
Resuscitation started by a bystander or witness (yes/no)	1.45 (0.62 to 3.36)
Time interval between the moment of collapse and the start of resuscitation (minutes)	0.85 (0.75 to 0.96)
Ambulance delay time (minutes)	0.89 (0.78 to 1.00)
First documented rhythm: VT/VF v other rhythm	5.72 (2.10 to 15.96)

VT, ventricular tachycardia; VF, ventricular fibrillation.

DEFINITIONS

Sudden cardiac arrest

Sudden cardiac arrest was defined as unexpected, non-traumatic loss of vital signs, such as consciousness, arterial pulse, blood pressure, and respiration without preceding complaints or within 24 hours of the onset of complaints.⁵ Witnessed SCA are arrests occurring in the presence of a bystander or emergency medical personnel.⁵ Unwitnessed SCA was defined as an SCA that occurred when a person was alone at the moment of the event and who was found unconscious or dead by a family member, neighbour, friend, etc.⁵

Acute myocardial infarction

Acute MI was diagnosed when the ECG showed the characteristic serial changes in Q waves and the ST-T segment. Furthermore a typical rise of all three enzymes (CK > 240 U/l, LDH > 450 U/l, and AST > 40 U/l) above the upper limit of normal was required; CK-MB fraction had to be > 5%.

Ischaemic event or primary arrhythmic event

Included in this group were patients with ECG abnormalities suggesting ischaemia rather than acute MI (ST depression, changing polarity of T waves) or when their ECG did not show changes typical for MI or ischaemia as described above. Further clinical work up confirmed ischaemia or a primary arrhythmic event as the most likely cause, and the CK-MB fraction was < 5%.

STATISTICAL METHODS

All data were analysed using the SPSS-PC statistical program. Statistical significance for differences have been tested by χ^2 analysis for proportions and Mann-Whitney U test for continuous variables. A p value < 0.05 was considered significant. When proportions showed a trend over the years, the χ^2 test for trend was calculated.

Multiple logistic regression analysis was performed to analyse the relation between the independent variables: age (continuously), sex (women is the reference category), presence of a previous cardiac history, resuscitation by witness or bystander, location of the event (outside home is the reference category), estimated time between collapse and the start of resuscitation (continuously), the ambulance delay time (continuously) and the first documented rhythm (0 is asystole, bradycardia or other rhythm; 1 is VT or VF), and the dependent variable survival, which was defined as discharged alive from the hospital. All variables were taken into consideration simultaneously.

A second regression model was constructed with the same variables; however, the time between collapse and the start of resuscitation and the ambulance delay time were included as two categorical variables. Odds ratios (OR) and their 95% confidence intervals (CI) were calculated.

Results

From 1 January 1991 until 31 December 1995, 638 SCA patients were registered, with an

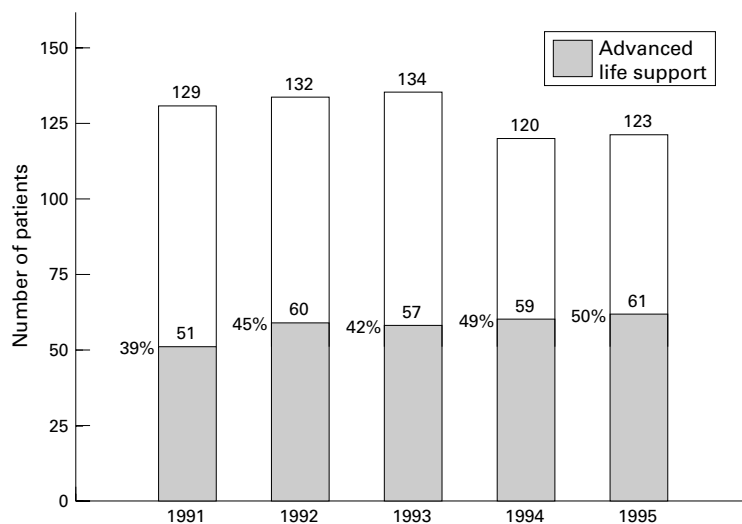


Figure 1 Annual number of SCA patients in whom advanced life support was applied.

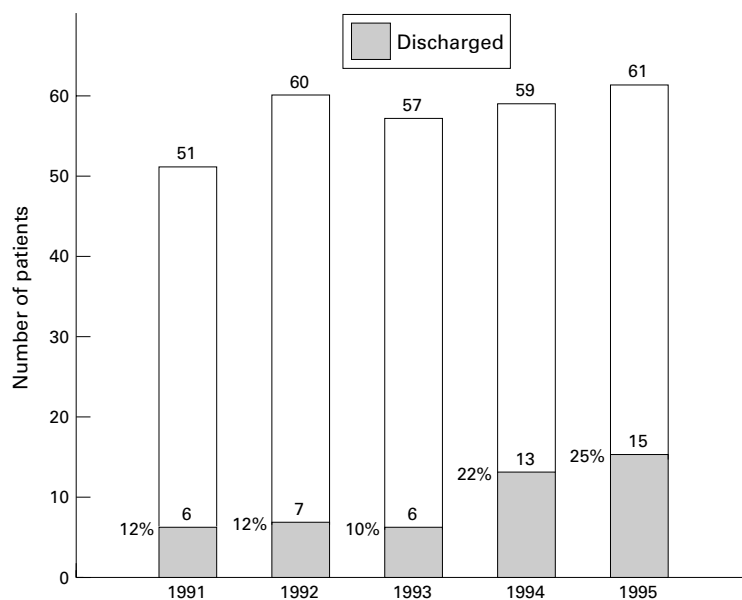


Figure 2 Annual number of SCA victims in whom advanced life support was applied and the number of patients who were discharged alive from the hospital.

annual incidence of 129, 132, 134, 120, and 123 victims, respectively. Thus, annual incidence did not change significantly over the years (9.8/10 000 inhabitants in 1991, 9.2/10 000 inhabitants in 1995). Age and sex distribution did not change significantly over the years.

Resuscitation was attempted in 288 of 638 (45.1%) SCA patients by the ambulance personnel. Resuscitation was successful in 47 of these 288 (16.3%) patients and these were discharged alive from the hospital.

CIRCUMSTANCES OF SUDDEN CARDIAC ARREST IN SURVIVORS

Table 1 shows baseline characteristics and circumstances of SCA of all survivors and non-survivors in whom resuscitation was attempted by the ambulance personnel. Mean (SD) age of survivors was 58.1 (11.3) years and 37 (79%) were men. A history of cardiac disease was present in 24 of the 47 survivors. SCA occurred at home in 24 of 47 survivors.

Seventeen were on the street or a public place, two were at work, SCA occurred during transport from home to the ambulance in three patients, during transport to the hospital in one. SCA occurred during the night (0000 to 0600) in five survivors, in the morning in nine survivors (0600 to 1200), in the afternoon (1200 to 1800) in 19 survivors, and during the evening (1800 to 0000) in 14 survivors. In 45 of 47 survivors a witness was present: in 19 a partner, in six another family member, in 11 a bystander, in four a nurse or physician, and in five both a partner and an ambulance nurse. In two survivors, SCA was not witnessed. These patients were found unconscious by their partners who immediately called an ambulance. In 28 survivors, resuscitation was initiated by a witness or bystander before the ambulance arrived. In 14 of these 28 cases resuscitation attempt was started by a nurse or physician. The mean estimated time interval between the moment of collapse and the start of the resuscitation attempt was 2.7 (3) minutes, and the ambulance delay time was 5.9 (2.6) minutes. The first documented rhythm by the ambulance personnel was VF in 38 survivors, VT in two, bradycardia in five, and asystole in two.

FACTORS THAT INFLUENCE RESUSCITATION SUCCESS RATE

The logistic regression model (table 2) shows that VT/VF as the first documented rhythm by the ambulance personnel was significantly positively associated with survival in resuscitated victims. A history of cardiac disease and longer time between the moment of collapse and the start of resuscitation were significantly negatively associated with survival.

A time delay between the moment of collapse and the start of resuscitation of less than four minutes and an ambulance delay time of less than eight minutes were significantly positively associated with survival (OR 3.3, 95% CI 1.3 to 8.6, and OR 3.6, 95% CI 1.3 to 10.5, respectively).

Figure 1 shows that the number of resuscitation attempts did not change significantly over the years. The number of SCA patients who survived more than 24 hours after successful resuscitation and were admitted to the coronary care unit of the hospital increased from 20% in 1991 to 38% in 1995 ($p < 0.05$). The number of SCA patients who were discharged alive from the hospital increased from 12% in 1991 to 25% in 1995 ($p < 0.05$) (fig 2).

Table 3 shows that during the five year period there was no significant change in baseline characteristics, place of event, number of bystander resuscitations, bystander success rate, time interval between the moment of collapse and the start of resuscitation, and ambulance delay time. There was also no difference in the number of victims found in VT/VF and in the number of SCA patients witnessed by the ambulance personnel.

Table 3 Comparison of factors influencing resuscitation success rates 1991–95

Variable	1991 (n = 51)	1992 (n = 60)	1993 (n = 57)	1994 (n = 59)	1995 (n = 61)
Men	43 (84%)	47 (78%)	44 (77%)	47 (80%)	43 (70%)
Cardiac history	35 (69%)	29 (48%)	31 (54%)	38 (64%)	30 (49%)
Age (years)					
20–40	2	0	3	4	1
41–60	22	23	18	25	28
61–74	27	37	36	30	32
Place: at home	27 (53%)	41 (68%)	35 (61%)	44 (75%)	39 (64%)
Rhythm VT/VF	28 (55%)	34 (57%)	32 (56%)	34 (58%)	35 (57%)
Time from collapse to resuscitation < 4 mins	24 (47%)	27 (45%)	29 (51%)	29 (49%)	30 (49%)
Ambulance delay time < 8 mins	39 (76%)	47 (78%)	38 (67%)	41 (69%)	43 (70%)
Bystander resuscitation	24 (47%)	19 (32%)	32 (56%)	30 (51%)	25 (41%)
Success rate bystander resuscitation	4/24 (17%)	4/19 (21%)	5/32 (16%)	7/30 (23%)	8/25 (32%)
Witnessed by ambulance nurse	3 (6%)	7 (12%)	2 (4%)	5 (8%)	9 (15%)

p value, not significant for all variables.

VT/VF, ventricular tachycardia/ventricular fibrillation.

CAUSES OF SUDDEN CARDIAC ARREST IN SURVIVORS

Acute MI was diagnosed in 24 of 47 survivors; in seven of 22 with a history of cardiac disease, and 17 of 25 without ($p < 0.05$). Of 24 patients with an acute MI, the location was anterior in 10 patients, posterior in nine, and inferior in four. In one patient the location of the infarct was not traceable because of multiple old infarctions.

An ischaemic event or a primary arrhythmic event caused by an old MI was most probably the cause of SCA in 19 patients. In four other survivors the causes of SCA were pulmonary embolism, complete AV block, ventricular tachycardia in a patient with severe mitral valve disease, and ventricular fibrillation as the first expression of the Wolff-Parkinson-White syndrome, respectively.

DIAGNOSTIC WORK UP AND INTERVENTIONS DURING HOSPITAL ADMISSION

In all but two survivors echocardiography was done after the event. In 11 of 21 survivors with, and in one of 24 survivors without, a history of cardiac disease the left ventricular ejection fraction (LVEF) was less than 40%.

Twenty of 24 survivors with an acute MI underwent coronary angiography. One significantly narrowed vessel ($> 50\%$ narrowed) was present in six survivors, two vessel disease in five, and three vessel disease in nine. Percutaneous transluminal coronary angioplasty was done in 12 survivors and coronary artery bypass grafting in two. Four patients received thrombolytic treatment, and six survivors received heparin and nitroglycerin.

Coronary angiography was done in 14 of 19 survivors with an ischaemic or primary arrhythmic event. In two patients one vessel was significantly narrowed, in six patients two vessels, and in a further six patients three vessels. In seven patients a defibrillator was implanted.

COMPLAINTS IN RELATION TO CAUSES OF SUDDEN CARDIAC ARREST

Of 24 survivors in whom an acute MI was diagnosed, 19 patients had chest pain before the event. In 13 patients chest pain started within one hour of SCA. The other six patients had had chest pain for more than one hour before SCA.

In 17 of 23 survivors in whom no acute MI was diagnosed, there were no complaints before SCA. Four survivors had severe dyspnoea within one hour of the event, while in two patients it was unknown whether they had any complaints.

FOLLOW UP

Of the 47 survivors, four men and two women were admitted to a nursing home after hospital discharge because of irreversible hypoxic encephalopathy. Mean (SD) age was 63 (11) years and two of these patients had a history of cardiac disease. In three patients acute MI, in two an ischaemic event, and in one patient a primary arrhythmic event had been diagnosed.

Forty three of the 47 patients survived for more than one year after the event. All four patients who died within a year of the event were men, and in three of them acute MI had been diagnosed. They had not been admitted to a nursing home. Three patients died suddenly, one because of pulmonary embolism. One patient died during peripheral vascular surgery.

Discussion

We have described circumstances and causes of out-of-hospital SCA in patients in whom resuscitation was attempted by ambulance personnel and who survived to hospital discharge. All patients were included in a five year prospective registry of out-of-hospital cardiac arrest in the Maastricht area in the Netherlands and were admitted to the same hospital.

In more than half of the survivors, SCA occurred during the day and half of all patients were not at home. These two circumstances may enhance the chance of being witnessed and being resuscitated immediately or within a few minutes. As shown by our and other studies, an increasing ambulance delay time (more than eight minutes) and an increasing estimated time between the moment of collapse and the start of resuscitation (more than four minutes) were important independent factors, negatively associated with survival.^{6–8} Increasing age was also negatively associated with survival, but this was not significant. Bystander resuscitation was significantly positively associated with survival (OR 2.2, $p = 0.04$) when the time between collapse and the start of resusci-

tation was excluded from the logistic regression model. Another important variable in this respect is VT or VF as the first documented rhythm. As in other studies^{2,9-12} most of our survivors had VF as the first documented rhythm, which was positively associated with survival in those in whom resuscitation was attempted. A history of cardiac disease was significantly negatively associated with survival. This may be explained by the fact that in those with such a history, cardiac function was already diminished before the event. Half of the survivors with a history of cardiac disease had an LVEF of less than 40% after the event, while this was the case in only one of those without such a history. Hallstrom *et al* suggested that co-morbidity was an important predictor for survival.¹³

The increase in resuscitation success rate over the years can be explained by many possible factors—for example, since the end of 1993 all ambulances have been equipped with portable defibrillators and portable apparatus for monitoring rhythm and blood saturation, and at that time, all nurses and drivers received a professional training in resuscitation.

Cardiac causes of SCA can be classified as ischaemic and non-ischaemic. Different manifestations of ischaemic heart disease include: acute MI, acute myocardial ischaemia, and a healed MI that serves as a substrate for VT deteriorating into VF.¹⁴ In all but one survivor the cause of SCA was cardiac. Of the patients who had coronary angiography during hospital stay, nearly 76.5% had two or three vessel disease. Myerburg and colleagues⁹ reported that 81% of the patients who had significant coronary artery lesions had two or three vessel disease.

In half of all patients an acute MI was diagnosed. Early studies have reported that an acute MI was diagnosed in only a minority of patients who were successfully resuscitated.^{1,2,9} In a study from Seattle, only 20% of the survivors had a new transmural infarction.¹ The aetiology of SCA was determined in 109 survivors studied by Myerburg *et al.*^{2,9} In 86 patients (79%) coronary artery disease was present, and in 31 (28%) acute myocardial necrosis was documented. In contrast, Dickey *et al* reported that the aetiology of VF was an acute MI in 69% of the patients who were successfully resuscitated (including those who died during hospital admission).³ Goldstein *et al*¹ reported that in 142 SCA patients with coronary heart disease who were resuscitated and discharged from the hospital, the cardiac arrest was classified as being secondary to an acute MI in 44%, an ischaemic event in 34%, and a primary arrhythmic event in 22%. Most of these patients (77%) had a history of cardiac disease. These differences in the number of survivors with an acute MI may be explained by the use of different criteria for acute MI (only transmural MIs) or by differences in baseline characteristics of survival groups. The higher number of patients in whom an acute MI was diagnosed in our study may be explained by the fact that half of the survivors had no history of cardiac disease. An acute MI was diagnosed in

68% of these patients and in only 32% of patients known to have cardiac disease.

In this study, the determination of the mechanisms of SCA was based on only a small fraction of all SCA patients; however, necropsy of SCA patients who were also included in the four year registry showed comparable results. In 96 of 127 necropsied SCA patients the cause of sudden death was cardiac. The underlying mechanism was coronary artery disease in 94 of 96 patients (mean age 58.9 (11.2) years, 72 men (77%), previous cardiac history 48 (51%)). This latter group was comparable with the survivors who had coronary artery disease in terms of mean age, sex, and history of cardiac disease. At necropsy, a recent MI was found in 58.5% patients, in 52% of the patients with and 65% of those without a history of cardiac disease.

It is not possible to determine how many acute MIs were the initiating factor and how many MIs were a consequence of SCA.² However, in most of our survivors with an acute MI, chest pain was reported before SCA. In more than two thirds of them, VF developed within one hour of the onset of chest pain.

As mentioned above, 24% of the necropsied group had a non-cardiac cause of SCA compared with only one of the survivors. This suggests that a non-cardiac cause of SCA is negatively associated with survival.

In our patients, one year mortality after discharge was 8.5%, which is lower than reported by others.^{10,11,15,16} One year mortality in those studies was around 20%. As reported by Schaeffer and Cobb,¹⁷ most of the recurrent SCA (within two years of initial SCA) occurred in patients in whom no acute transmural MI was diagnosed. Studies from Seattle¹ and Miami¹⁸ reported that the one year recurrence rate in survivors was about 30% and the two year recurrence rate 45%. The lower one year mortality rate in our study may be explained by the fact that in half of the survivors an acute MI was diagnosed, and by the intensive treatment and long term management of those in whom an ischaemic or primary arrhythmic event was diagnosed. In seven patients a defibrillator was implanted, which is associated with a reduction in cardiac mortality.¹⁹

In summary, in 51% of all SCA survivors, acute MI was diagnosed as the underlying mechanism of SCA. Complaints of chest pain before the event were present mainly in patients in whom a diagnosis of acute MI was made. SCA occurred immediately or within one hour of the onset of complaints in 87% of the survivors.

Findings in survivors suggest that acute MI is often the cause of SCA, especially in those without a history of cardiac disease. This emphasises the importance of educating the general population to go immediately to an area where advanced life support can be provided when symptoms suggest acute MI. The correct surrounding is not only important for early thrombolytic treatment but also for successful resuscitation if a lethal arrhythmia occurs.

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